Low-cost modifications of the traditional Ethiopian tine plough for land shaping and surface drainage of heavy clay soils: Preliminary results from on-farm verification trials*

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Summary

THE TRADITIONAL *ox-drawn Ethiopian plough (maresha) has been modified by ILCA for use in the construction of terraces for soil conservation and for making raised broadbeds and furrows to facilitate surface drainage on heavy clay soils. The two resulting implements are described in this paper. The preliminary results from their on-station and on-farm testing are also reported.*

The terracing plough has slightly lower power requirements than the maresha, while the broadbed maker requires about 50% more power than the traditional plough. The modified implements can be drawn by a pair of light (250 kg) zebu oxen. The costs of the modifications are approximately US$ 5 for the terracing plough and US$ 25 for the broadbed maker. Both implements can be made and maintained by village craftsmen.

Three cultivation passes with the terracing plough are needed to establish 4-m-wide, level terraces on land with 8% slope. Raised broadbeds (20 cm high and 120 cm apart) and furrows can be made at a rate of 0.4 to 1.2 ha/ox-pair working 7 hours a day, depending on the required uniformity of the beds and the moisture status of the soil. The broadbed and furrow (BBF) technology facilitates weed control and enhances surface drainage on heavy clay soils, which in turn results in better crop growth. The yields of traditional lines of bread wheat and teff grown on drained farmers' fields were about 80% and 25% higher respectively than those obtained on traditionally cultivated, fiat land. Results from on-farm trials indicated that making BBFs with the ox-drawn broad-bed maker requires considerably less human labour (16 hours/ha) than the traditional method of making BBFs by hand (60 hourslha).

Introduction

In the Ethiopian highlands, cultivated almost exclusively using animal power. The traditional wooden plough (*maresha;* Figure 1) has a pointed metal tine fitted to a handle and held by a metal hook suspended from the beam of the plough on an adjustable leather strap. The hook supports two flat, wooden wings, one on each side of the implement, and both wings are attached to the beam with a steel pin. The *maresha* disturbs the soil, lifts it and turns it equally on each side of the plough, leaving a narrow furrow and two small ridges behind.

Most highland farmers own a *maresha,* but only about one-third of them own two oxen (Ethiopian Ministry of Agriculture, unpublished data). The majority enter into one or more of the traditional renting and exchange agreements for draught oxen in order to be able to cultivate their land. To help relieve this draught-power constraint, ILCA developed a yoke and harness and a modified version of the traditional plough that can be drawn by a single ox. The modified *maresha* has been described by Gryseels et al (1984) and its on-farm performance reported by Gryseels and Jutzi (1986).

This paper reports on two further modifications to the *maresha*, which allow controlled soil movement. The first, the terracing plough, shifts soil to one side only when ploughing. The second, the broadbed maker, shapes the topsoil into broadbeds and furrows, thereby improving the drainage of surface water on heavy clay soils. Both implements have been developed by ILCA's Highlands Programme which is based at Addis Ababa, Ethiopia.

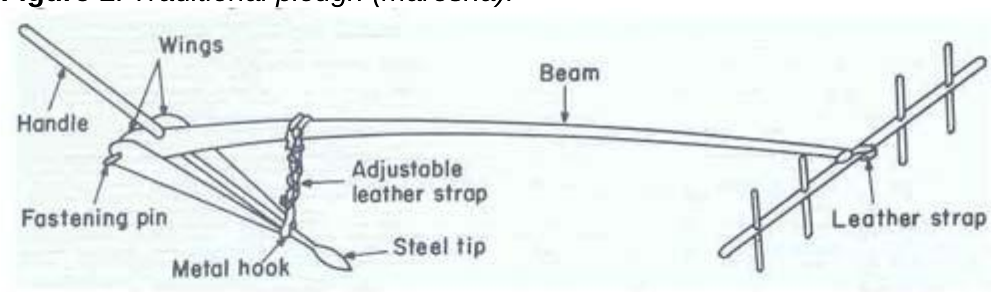
A detailed description of both the terracing plough and the broadbed maker is given below. Their potential use and impact on soil and water conservation, crop yields and farm-level labour economy are discussed on the basis of on-station and on-farm verification trials carried out in 1985 and 1986.

The terracing plough

Design and operation

The terracing plough (Figure 2) is made by replacing the two flat wings of the *maresha* with one wooden, mouldboard-shaped wing which can be shifted from one side of the beam to the other without detaching it from the implement (reversible wing). The light tip of the wing is reinforced with a flat steel sheet and there are two metal rings passing through it, which attach the wing loosely to the handle of the plough. The rings are made of iron rods. The mouldboard wing is fixed to the beam with the same metal pin used in the traditional *maresha.*

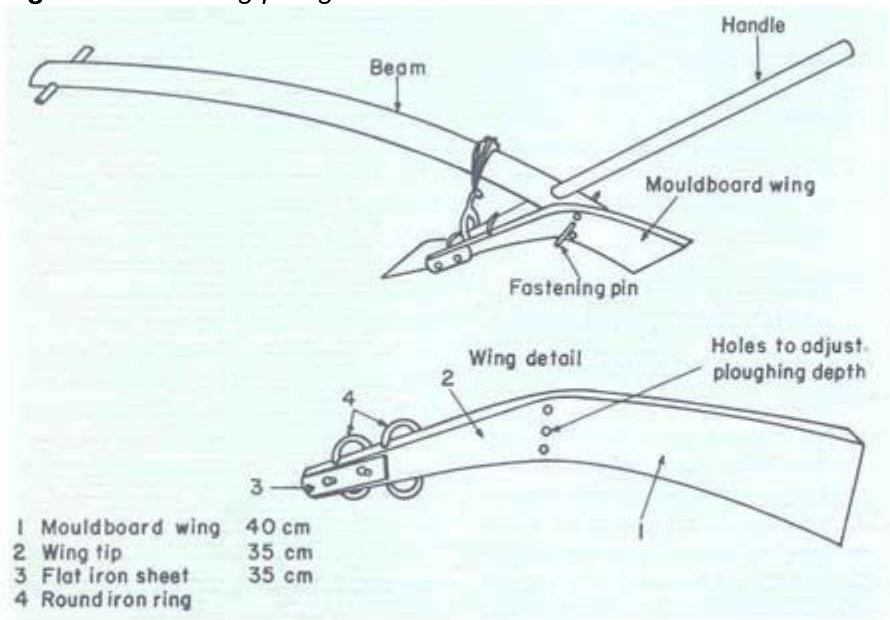
Figure 1. *Traditional plough (maresha).*



The wing can be moved from one side of the beam to the other by pulling out the metal pin, swinging the wing underneath the beam to the other side and fixing it again with the pin. Thus the plough does not need any further modification to function as a reversible plough. The reversible wing can be fitted to the traditional plough in about 3 minutes.

The materials used to modify the *maresha* into a terracing plough include a 40 x 5 cm metal sheet of about 4 mm thickness, two 7-cm bolts, an 80-cm-long iron rod (10 mm in diameter) with two welding points, and about 3 kg of hardwood, preferably of acacia, for the mouldboard wing. The total cost of the materials is about US$ 5.

Figure 2. *Terracing plough.*



The terracing plough is operated in the same way as the traditional plough, with only one exception: the wing must be reversed at the end of each pass in order to shift the soil to one side only. The reversal of the wing takes about 20 seconds.

Performance

The animal power needed to pull the implement was determined using the method described by Abiye Astatke et al (1986). The force developed by each pair of oxen was measured with a portable battery-powered dynamometer[1] consisting of a load cell inserted between the yoke and drawbar of the plough and a digital indicator connected to the load cell by a cable. The minimum and maximum force (kN) over 20 m and the time taken to travel the distance were recorded for a series of passes. The working heights of both the yoke and the implement hitch and the length of the draught chain were measured, and the force parallel to the ground was calculated. Power consumption was established by multiplying the actual force developed (kN) by speed (m/sec).

[1] Supplied by Novatech Measurements Ltd, UK.

Average power consumption for the third pass with the traditional *maresha* is 660 ± 112 W (Abiye Astatke and Matthews, 1982). The power needed to make the third pass with the terracing plough is 534 ± 110 W (Jutzi, unpublished data), which is about 80% of the power requirement of the traditional plough. The terracing plough has a lower power requirement than the traditional plough because it penetrates less deeply when shifting loose soil to one side.

An average of 3.3 passes were sufficient to establish 4-m-wide, level terraces on a clay-loam field with 8% slope. The borders of the terraces (about 30 cm high) were stabilised with rows of *Sesbania sesban.* In a 7-hour work-day, one ox-pair prepared 1911 ± 298 m^2 of finished terraces on this slope. Monitoring work on 22 terraces (420 m long), it was found that one ox-pair can cover about 1 ha in 5 days, which is comparable to the time spent in cultivating the same amount of land with the traditional plough. The terraces reduce soil loss and conserve water by slowing and reducing runoff. More stable crop yields can be expected immediately due to increased water availability, and in the longer term also due to soil and fertility conservation, especially when leguminous browse species are used to stabilise terrace borders.

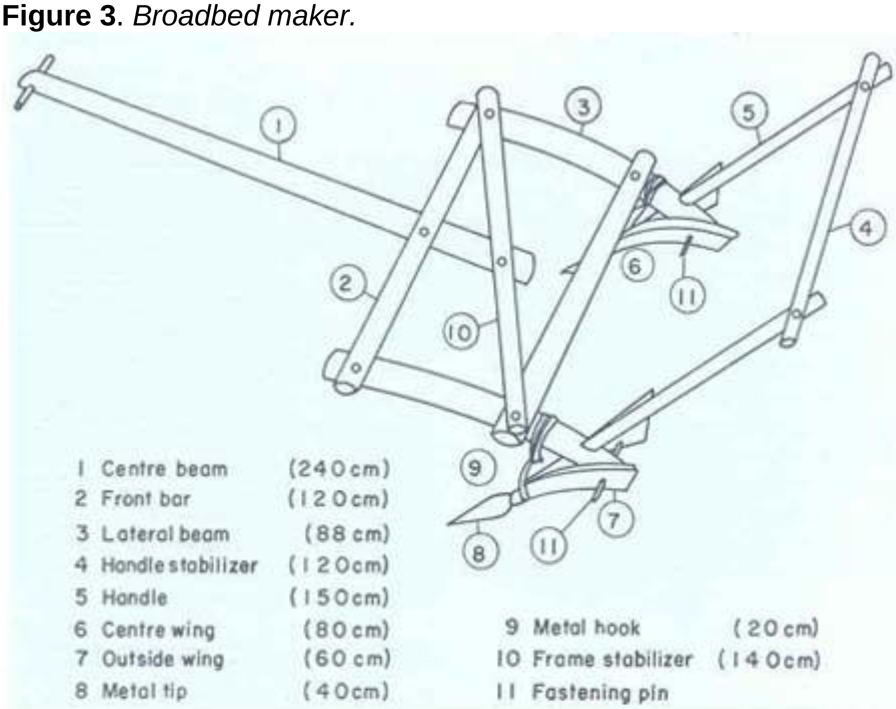
The broadbed maker

Design and operation

Plant growth on deep black clay soils (Vertisols, black cotton soils) is reduced by waterlogging (Kanwar et al, 1982; Ryan and von Oppen, 1983; Haque and Jutzi, 1984), which is especially serious in areas with high annual rainfall. To overcome this constraint, the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) carried out experiments with different systems of surface soil drainage and developed an effective but expensive animal-drawn toolbar with various attachments (ICRISAT, 1985; 1986). Low-cost devices are, however, essential for the successful adoption of improved land management practices in the subsistence farming systems of sub-Saharan Africa, where Vertisols account for 97 million ha of land. ILCA therefore developed a broadbed maker based on the traditional *maresha,* using cheap and widely available materials for the modifications.

The broadbed maker is made from two local ploughs whose main beams are shortened to about 90 cm and fitted in a simple wooden frame (Figure 3). The flat wings of the traditional ploughs are replaced by four mouldboard-shaped wooden wings, comprising two large centre wings throwing earth inwards to create the broadbed and two smaller wings pushing earth to the outside. To facilitate operation, the two handles are joined with a wooden beam.

Figure 3. *Broadbed maker.*



The total weight of the broadbed maker is about 30 kg, depending on the type of wood used for the connecting beams and the wings. In contrast, the traditional *maresha* weighs approximately

20 kg. The cost of the modifications on the broadbed maker is about US$ 25 for 8 bolts, an 8-m long wooden pole and 8 kg of hardwood for the four wings.

Performance

Power requirements for the broadbed maker are higher than those for the *maresha* (O'Neill and Howell, 1986). The power needed for both implements was determined in a comparative study by measuring the force in the draught chain (using a standard Novatech load cell), the angle of pull (using a Ferranti potentiometric clinometer) and the forward speed (using a Dickey-John radar velocity sensor). In a well-worked field, the average power consumption of the *maresha* was 398 ± 61 W (17 observations), while the broadbed maker consumed 634 ± 81 W (13 observations). The power requirement of the broadbed maker was considerably less than the power (about 800 W) that can be developed by a pair of light (250 kg LW) local zebu oxen hitched to the implement by a rigid neck yoke.

A pair of oxen drawing the broadbed maker can prepare between 0.4 and 1.2 ha of BBFs per day, depending on the number of passes made and the moisture and tilth status of the topsoil. Normally two passes are required in order to provide a uniform shape to both the broadbed and the furrow. A chain attached to the two centre wings acts as a simple harrow and provides uniformity in surface tilth.

Effects of the BBF technology on crop yields and labour input

The better drainage due to the BBF technology increases crop growth. This was demonstrated in a series of on-farm verification trials conducted with bread wheat (8 participating farmers) and teff (15 participating farmers) at Debre Zeit, central Ethiopian highlands, in 1985. In these trials, the grain and straw yields of bread wheat grown on raised broadbeds were 78% and 56% higher respectively than those obtained on traditionally cultivated plots. Teff *(Eragrostis teff)* which is an important Vertisol crop relatively tolerant of waterlogging, produced 25% and 23% higher yields of grain and straw respectively when planted on drained plots. The potential impact of this low-input technology on food production in Ethiopia, which has 8 million ha of Vertisols in the high-rainfall highland areas, is considerable.

The broadbed maker is currently being tested in extended on farm verification trials on the Inewari plateau in northern Shewa and in other Vertisol areas in Ethiopia. At Inewari, broadbeds and furrows are traditionally made by hand, with a labour input of about 60 hours/ha. When the broadbed maker was used (operated by a single operator), the human labour input for making BBFs was reduced to 16 hours/ ha. Under the traditional system, total labour inputs for land preparation, seeding and surface drainage are about 120 hours/ ha, compared with 75 hours/ha for the broadbed maker. This represents a 40% increase in labour productivity, assuming that crop yields are the same for both systems. Early indications in mid-1986 were that plots cultivated with the broadbed maker would outyield the traditionally cultivated plots, because of the greater uniformity of the BBFs.

Further developments

The broadbed maker can also be used as a toolbar. Two prototypes of attachments to the broadbed maker are currently under testing:

A *blade harrow* consisting of a metal blade mounted between the tines and supported with an extended bolt at the center-rear of the frame. This implement cuts the soil uniformly some 5 to 10 cm below the surface, thus disturbing and killing most weeds. In addition to reducing substantially the power and time inputs needed for Vertisol cultivation, the blade harrow will enable permanent BBFs to be created, with only surface cultivation needed each year to control weed regrowth. The cost of the blade attachment is about US$ 7.

The second attachment is a *row planter* mounted on the rear section of the broadbed maker. It has a rotary seed agitator driven by a star-wheel which runs on one side of the broadbed maker on the adjacent broadbed. The prototype has two hoppers, one for seed (compartmented for simultaneous planting of intercrops) and one for fertilizer. The planter can plant 1 to 6 rows on a broadbed with 70 cm top width. Metering discs under the rotary agitator allow planting of conventional crop seed at desired rates. A chain attached to the two inside wings of the broadbed maker covers the seed in the planting rows. The rows are opened by vertically mounted, metal row-makers fixed in front of the rear section of the broadbed maker. The cost of the planter is expected to be about US$ 40.

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